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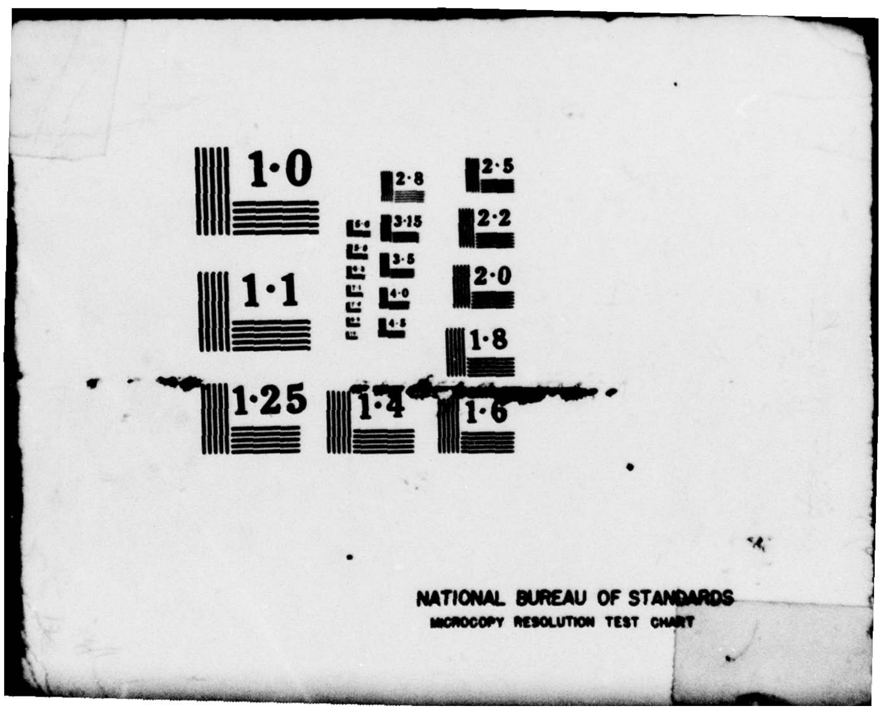
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Technical Memorandum

SPIROMETRIC PERFORMANCE OF AIRCREW USING THE MOLECULAR SIEVE OXYGEN GENERATOR IN HIGH PERFORMANCE FLIGHT

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A comparative evaluation of the pulmonary effects of pure oxygen (LOX) versus the product of the molecular sieve oxygen generator (MSOG) was conducted by eight aircrewmen in an EA-6B aircraft during normal and high g flight maneuvers. Significant reductions in vital capacity and expiratory flow rates immediately following high g flights were observed only in those subjects breathing 100% oxygen. Spirometric values following nonaerobatic flight, however, were not significantly altered by either gas system. Within

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the limited scope of this study, it appears that the small amount of inert gases present in the MSOG product offers a measurable level of protection against high g absorptional atelectasis in aviators.

PREFACE

The Naval Air Systems Command AIRTASK A310-310C/053A/8R041-01-001 tasked the Naval Air Test Center with quantifying the effects of a new Molecular Sieve on Onboard Oxygen Generating System on pulmonary function. This analysis involved the measurement of Forced Vital Capacity (FVC), the FVC in the first second of exhalation (FEV_1), and the forced expiratory flow rate from 25% to 75% of the FVC (FEF_{25-75}). Comparative data were obtained utilizing the Standard Liquid Oxygen System. This paper is being prepared for publication in Aviation Space and Environmental Medicine.

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J. G. WISSLER
Commander, Naval Air Test Center

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INTRODUCTION

BACKGROUND

1. Transient alterations in pulmonary function are well-known occurrences in normal subjects both during and immediately after high performance g maneuvers in which 100% oxygen is breathed. Diminution in lung volumes (1, 2, 3), air flow mechanics (2), and oxygen transfer (4, 5) have all been reported in this environmental setting. Additionally, symptoms of chest tightness, chest pain, cough, difficulty in breathing, and roentgenographic changes characteristic of subsegmental atelectasis have been reported in a high proportion of aviators after such flights (1, 3).

2. The major pathogenetic factor involved in pulmonary degradation appears to be alveolar collapse (1, 2, 3, 6, 7). The important factors promoting such a collapse are: the mechanical compression of lung tissue by acceleration forces (4 5, 7, 8, 9); absorption atelectasis due to 100% oxygen usage (10, 11, 12, 13, 14, 15); and elevation of the diaphragm by inflation of a protective anti-G suit (8, 16).

3. The contribution of absorptional atelectasis is of particular interest, for it depends to a large extent on the gas composition in the alveolus. If the alveolus is filled with a gas that is rapidly transferred to the blood (such as oxygen), then decreases in the ventilation/perfusion ratio (as can occur at the lung bases under +Gz acceleration), complete gas absorption and alveolar collapse will be promoted (3, 12). However, if only a small amount of a gas that does not rapidly diffuse into the blood stream is present in the alveolus, it serves to "hold open" the alveolus and effectively prevent collapse (14, 15).

PURPOSE

4. A new Molecular Sieve Oxygen Generator (MSOG) is currently being evaluated as a source of aviator's oxygen for use in tactical jet aircraft. The MSOG can only deliver a maximum of 95% oxygen, the remainder being composed primarily of the inert gas argon. It was hypothesized that perhaps this small amount of inert gas might prevent the postflight atelectasis associated with high g flight and 100% oxygen usage. To test this hypothesis, pulmonary functions were measured postflight in the aircrewmen breathing the MSOG gas and in crewmen breathing standard Liquid Oxygen (LOX) gas.

METHOD OF TEST

5. Eight aircrewmen were assigned to evaluate the MSOG in an EA-6B aircraft. All aircrewmen were active duty Navy personnel who were physically fit by Naval Aviation Standards.

6. Testing consisted of a forced vital capacity maneuver performed with an Ohio 840 Spirometer attached to an X-Y Plotter. Spirometer calibrations were checked daily. Testing was done prior to flying and then immediately upon completion of the flight. Two additional vital capacity maneuvers were performed over a 45-min period following completion of the flight. Demonstration of the forced vital

capacity maneuver, close observation, and vocal encouragement ensured maximum effort. A minimum of three trials were performed by all subjects. The trial with the highest summation of forced vital capacity and forced expiratory volume in 1 sec was utilized for statistical analysis. Pulmonary functions recorded from the testing maneuver were: the Forced Vital Capacity (FVC), the FVC in the first second of exhalation (FEV_1), and the forced expiratory flow rate from 25% to 75% of the FVC (FEF_{25-75}). Values were corrected to Body Temperature and Pressure Saturated (BTPS) with water vapor. Percent changes from preflight were calculated.

7. Pulmonary function data were collected after each of four flights, two of which were acrobatic with high g forces (4-5 +Gz) in an EA-6B and two of which were "straight and level" (nonacrobatic) flights. During each flight, the command pilot and medical observer breathed 100% oxygen from the LOX system while the copilot and a fourth aircrewman breathed MSOG gases. Thus, a design of two control subjects (LOX) and two test subjects (MSOG) existed.

8. Test data were subjected to a three-way analysis of variance (gas system, flight profile, and time). Then, t-tests were used to evaluate a priori mean comparison. The differences between means were tested for significance within time periods and across gas mixtures.

RESULTS AND DISCUSSION

9. The physical characteristics and baseline spirometric data on the eight subjects used in this study are given in table I.

Table I

Physical Characteristics and Baseline Spirometry on the Two Test Groups

Breathing Gas	No. of Subjects	Mean Age (yr)	Mean Ht (cm)	Mean Wt (kg)	Baseline Spirometry		
					FVC (ℓ)	FEV_1 (ℓ)	FEF 25-27 (ℓ/sec)
LOX	5	35	183	74	5.47	4.47	4.73
MSOG	3	32	183	83	6.23	4.96	4.97

As can be seen, the three subjects breathing MSOG gases were slightly younger, heavier, and had larger vital capacities and expiratory flow rates than the five subjects who used 100% oxygen.

10. Significant main effects were obtained for gas systems for FVC ($F = 37.91$, $df = 1/40$, $p<.01$), FEV_1 ($F = 43.50$, $df = 1/48$, $p<.01$), and FEF_{25-75} ($F = 15.07$, $df = 1/48$, $p<.01$). The interaction of gas system versus flight profile was significant for FVC ($F = 6.37$, $df = 1/48$, $p<.05$) and FEV_1 ($F = 8.01$, $df = 1/48$, $p<.01$).

11. Postflight respiratory measurements are summarized in table II and the percent changes from baseline are shown in table III. The spirometric measurements in table II represent the mean value of the two aerobatic flights and two nonaerobatic flights. The data show a marked and significant decrease ($p<.05$) in vital capacity and expiratory flow rates immediately following aerobatic flight in those subjects breathing 100% LOX. (These values seemed to partially return to baseline levels after 45 min.) In the subjects breathing MSOG gases, however, the decreases in spirometric functions after postaerobatic flight were not statistically significant. As shown in table II, there was a significant difference between the two groups prior to flight and these differences remained statistically significant 45 min postflight. Spirometric values following nonaerobatic (straight and level) flight were not significantly altered by either gas system.

Table II

Summary Data of Respiratory Measurements

Flight Profile	Pulmonary Test	Gas System	Baseline	+Postflight 1	Postflight 2	‡Postflight 3
Aerobatic (High g)	FVC (ℓ)	LOX	5.25	4.03*	4.43	4.56
		MSOG	6.74**	6.23**	6.49**	6.65**
	FEV_1 (ℓ)	LOX	4.37	3.31*	3.47	3.62
		MSOG	5.30**	5.08**	5.15**	5.00**
	FEF (ℓ/sec)	LOX	4.86	3.42*	3.68*	3.72*
		MSOG	5.25	4.76**	4.87**	4.98**
Nonaerobatic (Straight/Level)	FVC (ℓ)	LOX	5.61	5.24	5.48	5.52
		MSOG	6.48	6.09	6.30	6.27
	FEV_1 (ℓ)	LOX	4.54	4.22	4.41	4.41
		MSOG	5.12	4.85	4.96	4.95
	FEF (ℓ/sec)	LOX	4.72	4.17	4.10	4.13
		MSOG	5.33	4.74	4.79	4.90

*Significantly different from baseline $p<.05$.
**Significantly different between gas system $p<.05$.
+Immediately postflight.
‡45 min postflight.

Table III

Changes in Postflight Spirometric Values from Baseline

Flight Profile	Time of Postflight Measurement	Gas Mixture	Number of Subjects	% Decrease in FVC	% Decrease in FEV_1	% Decrease in FEF_{25-75}
Aerobatic	Immediate	LOX	4	23	24	30
		MSOG	4	8	4	9
	45 min Postflight	LOX	4	13	17	23
		MSOG	4	1	6	5
Level	Immediate	LOX	4	7	7	12
		MSOG	4	6	5	11

CONCLUSIONS

12. The reuslts of this study confirm the works of others (1, 2, 8) who have demonstrated decreased vital capacity and expiratory flow rates in high g performance flights in which 100% oxygen was breathed. Of particular interest in this study is that the subjects breathing MSOG gases during these same high g flights did not demonstrate the same deterioration in pulmonary function found in subjects breathing 100% oxygen. As expected, nonaerobatic (straight and level) flights did not cause changes in pulmonary function in subjects on either gas system.

13. The findings reported in this study must be viewed with some caution. This study was only a part of an extensive evaluation program for the MSOG unit and the testing protocol had to conform to that of the overall program. Consequently, the same subjects could not always be used for the flights and the subjects could not be tested on both gas systems. In addition, the groups could not be matched for size, age, smoking habits, flight experience, etc. It is possible that factors other than the breathing gas mixtures accounted for the differences observed in this study. Nevertheless, it is believed that at least some of the large differences observed were due to the different gas mixtures. It thus appears that the MSOG gas does offer protection against the atelectasis associated with high g performance flights and 100% oxygen utilization.

14. The most likely explanation for the protection against atelectasis is the fact that MSOG gas always has at least 5% inert gas present (18). In this study, during the high g maneuvers, the oxygen concentration ranged from 83% to 93%, the remainder of the gas mixture being composed of argon (5%) and nitrogen. To understand how MSOG gas prevents alveolar collapse, it is necessary to consider both the factors affecting gas input into the alveolus (ventilation) and gas transfer from the alveolus to the pulmonary capillary (diffusion and perfusion). Collapse of an alveolus occurs when gas transfer exceeds ventilation. Reduced ventilation can result from a reduced barometric pressure, intrinsic lung disease, or from external compression of the lung by acceleration forces or flight equipment (7). Transfer of a gas from the alveolus to blood increases with greater perfusion, higher alveolar capillary pressure gradients, and better gas diffusion and solubility characteristics (14, 19). Alveolar collapse could thus be expected under high g stress with high alveolar concentrations of oxygen, a gas with high blood solubility and a high alveolar capillary pressure gradient. Ernsting (3) calculated that under high +Gz acceleration with high oxygen demands and 100% inspired oxygen, alveoli could collapse in less than a minute.

15. The presence of an inert gas in the alveolus tends to "brake" alveolar collapse because, being inert, this gas is essentially in equilibrium with the blood and no appreciable alveolar capillary pressure gradient exists. Thus, even in the presence of a very low ventilation/perfusion ratio, the decreased transfer of this inert gas out of the alveolus serves to hold open the alveolus for many hours (12, 13, 15, 19). How much inert gas must be inspired to prevent absorptional atelectasis is related to the degree of ventilation/perfusion imbalance present and the time allowed for collapse. Dantzker et al (12) have calculated that lung units with very low ventilation/perfusion ratios (.0001) will collapse in 5 to 6 min if the alveolus is

ventilated with 100% oxygen. If the inspired oxygen concentration is decreased to only 90%, however, the time to collapse will be greater than 30 min. Additionally, there is clinical evidence that at least 5% nitrogen in an otherwise pure oxygen breathing mixture will prevent absorptional atelectasis for 19 hr in individuals with abnormal airways (15). The results of this present study, that at least a 7 to 13% inert gas mixture seems to prevent atelectasis for the duration of a high g flight, would seem to be in agreement with these observations.

16. An alternative explanation for preventing atelectasis is a reduced direct oxygen toxicity to the tracheo-bronchial tree with reduced oxygen concentrations in the breathing mixture. While this is theoretically possible, most reports on direct oxygen toxicity suggest that at least several hours of exposure are necessary for any such changes to be clinically evident (11, 20). Since the flight tests in this study lasted only 60 to 90 min, this mechanism of protection is unlikely.

17. Military specifications currently call for 100% oxygen systems in all tactical jet aircraft. The arguments for and against such a specification are beyond the scope of this report. It would appear, however, that at least one advantage to the presence of a small amount of inert gas in the aviator's breathing mixture is a certain degree of protection against high g absorptional atelectasis associated with oxygen usage.

REFERENCES

1. Langdon, D. E. and Reynolds, G. E., 1961, Postflight Respiratory Symptoms Associated with 100% Oxygen and G Forces, Aerospace Med. 32: 713-718.

2. York, E., 1967, Postflight Discomfort in Aviators: Aeroatelectasis, Aerospace Med. 38: 192-194.

3. Ernsting, J., 1960, Some Effects of Oxygen Breathing in Man, Proc. Roy. Soc. Med. 53: 96-98.

4. Barr, P. O., 1962, Hypoxemia in Man Induced by Prolonged Acceleration, Acta. Physiol. Scand. 54: 128-137.

5. Alexander, W. C., Sever, R. J., and Hoppin, F. G., 1966, Hypoxemia Induced in Man by Sustained Forward Acceleration While Breathing Pure Oxygen in a 5 PSI Absolute Environment, Aerospace Med. 37: 372-378.

6. Turrios, T., Nobrega, F. T., and Gallagher, T. J., 1967, Absorptional Atelectasis Breathing Oxygen at Simulated Altitude: Prevention Using Inert Gas, Aerospace Med. 38: 189-191.

7. Woods, E. H., Nolan, A. C., Donald, D. E., and Cronin, L., 1963, Influence of Acceleration Upon Pulmonary Physiology, Fed. Proc. 22: 1024-1034.

8. Hude, A. S., Pines, J., and Saito, I., 1963, Atelectasis Following Acceleration: A Study of Casuality, Aerospace Med. 34: 150-157.

9. Hershgold, E. J., 1960, Roentgenographic Study of Human Subjects during Transverse Acceleration, Aerosapce Med. 31: 213-219.

10. Burger, E. J., 1967, Pulmonary Mechanics Associated with Oxygen Toxicity and a Suggested Physiological Test for Susceptibility to the Effects of Oxygen, Aerospace Med. 38: 507-513.

11. Clark, J. M., 1971, Pulmonary Oxygen Toxicity: A Review, Pharmacol. Rev. 23: 37-133.

12. Dantzker, D. R., Wagner, P. D., and West, J. B., 1975, Instability of Lung units with Low V/Q Ratios During Oxygen Breathing, J. Appl. Physiol. 38: 886-895.

13. Burger, E. J. and Macklem, P., 1968, Airway Closure Demonstration by Breathing 100% Oxygen at Low Lung Volumes and by Nitrogen Washout, J. Appl. Physiol. 25: 139-148.

14. Rahn, H. and Fahri, L. E., 1963, Gaseous Environment and Atelectasis, Fed. Proc. 22: 1035-1041.

15. Dubois, A. B., Turaids, T., Mammen, R. E., and Nobrega, F. T., 1966, Pulmonary Atelectasis in Subjects Breathing Oxygen at Sea Level or at Simulated Altitude, J. Appl. Physiol. 21: 828-830.

16. Lewis, B. M., Forster, R. E., and Beckman, E. L., 1958, Effect of Inflation of a Pressure Suit on Pulmonary Diffusion Capacity in Man, J. Appl. Physiol. 12: 57-64.

17. Harris, D., NAVAIRTESTCEN Project Test Plan, Onboard Oxygen Generating System (OBOGS), of 14 Feb 1978.

18. Miller, R. L., Theis, C. W., Stork, R. L., and Ikels, K. G., Molecular Sieve Generator of Aviator's Oxygen: Breathing Gas Composition as a Factor of Flow, Inlet Pressure, and Cabin Altitude, USAF - SAM Report SAM-TR-77-40, of Dec 1977.

19. Dale, W. A. and Rahn, H., 1952, Rate of Gas Absorption During Atelectasis, Am. J. Physiol. 170: 606-615.

20. Sackner, M. A. Landa, J., Hirsch, J., and Zapata, A., 1975, Pulmonary Effects of Oxygen Breathing, Ann. Int. Med. 82: 40-43.

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